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Systematic Review

New Decade, Same Concerns: A Systematic Review of Agricultural Literacy of School Students

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Abstract: In this new decade of the twenty-first century, research reports the same concerns about agricultural literacy in primary and high school students globally. A systematic review of agricultural literacy studies published between 2000 and 2020 which assess the agricultural literacy of the target population; evaluated an agricultural education program or curriculum; or developed instruments to measure agricultural literacy was conducted. The review method followed an internationally recognized protocol for selecting, screening, analyzing, and reporting outcomes. Results found that definitions of agricultural literacy have evolved from an awareness to a measure of a deeper understanding developed throughout the years of formal schooling by both formal and informal education and experiences. Informal agricultural knowledge may be gained through numerous sources and misconceptions are apparent even among those with informal familial knowledge networks. Developing agricultural literacy in school-aged children through formal education is critical. Recommendations offer innovative ways of developing agriculturally literate young people that can be used to design, deliver and evaluate programs which aim to increase the agricultural literacy of primary and secondary students across the globe.

Keywords: agricultural literacy; secondary school students; primary school students; agricultural education

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1. Introduction

The agricultural literacy of current and future generations of young people is of significant economic, social, health and environmental concern. Previous research has shown that an agriculturally literate society is vital if food production is to meet the needs of, "an anticipated global population projection of nine billion people by 2050" [1]. Yet, a systematic review of agricultural literacy research in the United States between 1988 and 2011 found that while some programs for students, teachers and their local community were successful in increasing agricultural literacy in the short-term, "many populations are still agriculturally illiterate" [2].

In both developed and developing countries, if young people are not agriculturally literate upon leaving formal education, then their capablities for knowing and addressing global food supply chain insecurities now and in the future will be impaired. Addtionally by addressing this issue, the next generation will be encouraged to aspire to a career in agriculture which is vital to attracting and retaining the future workforce [3–5]. This paper revisits the problem as an urgent priority for primary and secondary students, and aims to identify what is currently known about agricultural literacy levels through a systematic review of international research studies published over the last 20 years.

In recent studies from Africa, Australia, China, Indonesia and the United Kingdom, curriculum is consistently claimed to be the core vehicle for agricultural literacy development throughout the years of formal schooling yet use of the term as a measurable learning outcome is implicit rather than explicit [6–12]. Being considered agriculturally literate requires "knowledge and understanding of agriculturally related scientific and technologically-based concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity" [13]. This reflects the multiliteracies of domain-specific disciplinary discourses (e.g., science, technology, mathematics) together with socio-cultural understandings of agricultural literacy acquired by breaking the codes of different values, beliefs and knowledge systems, to make meaning through informed critical analysis and use in various contexts [14,15]. The knowledge systems which develop and support agricultural literacy may include but are not limited to, food and fibre production, natural resource ecosystems, and socio-economic sustainability of urban, peri-urban, rural and remote communities. Thus, as Meischen and Trexler (2003) concluded from their investigation of rural primary school students in the United States, an agriculturally literate person would, "be able to (a) engage in social conversation, (b) evaluate the validity of media, (c) identify local, national, and international issues, and (d) pose and evaluate arguments based on scientific evidence".

Three questions guided this systematic review of literature reporting on the agricultural literacy of young people in primary and secondary schools globally over the last twenty years from January 2000 to December 2020. First, what methodological approaches have framed research into the agricultural literacy of primary and secondary school students globally? Second, what insights can be obtained from those research findings as to the efficacy or otherwise of interventions designed to foster students' agricultural literacy? Third, what recommendations were made that offer innovative ways of developing agriculturally literate young people? The method by which the literature was selected for analysis is presented in the next section. Subsequent sections present results relevant to each of those guiding questions, followed by a discussion of implications for embedding agricultural knowledge and capabilities in twenty-first century learning design, implementation and evaluation.

2. Materials and Methods

The transparent method by which the literature was selected for analysis was adapted from the processes of the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) protocol [16], and informed by debates in the literature regarding the naming of reviews as either systematic or scoping [17,18]. The purpose of this review was to develop a systematic process to "uncover international evidence" of research into the concept of agricultural literacy in the context of formal schooling; "investigate conflicting practices" and current practices in developing agricultural literacy; and produce recommendations to "guide future decision-making" in this field of education [17]. The methods section sets out the search strategy, sources of evidence for selection, data extraction criteria, data analysis and its presentation.

It began with identifying reputable scholarly sources, screening to identify eligibility according to key words and inclusion/exclusion criteria, then including relevant studies for detailed analysis. An analytic matrix was then established to identify specifics of the research aim and questions, study type, methodological design, methods of data collection and analysis, ethical considerations, major findings and recommendations.

To begin the selection process, databases such as EbscoHost, Education Database, ERIC, ProQuest, Agricultural Science Database, Scopus and Google Scholar were considered to be reputable sources as were the key English language journals in the field; namely, the Journal of Agricultural Education and the Journal of Agricultural Education and Extension. Key words and phrases included in the searches were "agricultural literacy" and "school*/student*/technical/vocational/kindergarten/17 years/18 years" to capture agricultural literacy literature related to schools and school-aged persons.

The inclusion criteria adopted for selection of sources were:

- Studies conducted on samples composed of school students, with or without inclusion of teachers in the study.
- Empirical studies engaging with the concept of agricultural literacy.
- Studies conducted either within or outside of the normal school setting.
- Studies conducted outside of the school setting which occurred during class time.
- Peer reviewed research articles and conference proceedings published from 2000 to 2020.

The exclusion criteria adopted for the selection of sources were:

- Studies which included adult learners, farmers, university students or community or extension learning models which were not targeted at school-aged children.
- Studies noted specifically as being 4-H extension activities delivered in the USA as an extracurricular program.
- Studies published in languages other than English.

Figure 1 illustrates schematically the application of this process through phases of literature identification, screening to remove duplicates, determining eligibility according to the inclusion and exclusion criteria applied first to titles and abstracts, then after discarding those not eligible, a full-text reading of all remaining literature to determine those selected for detailed analysis. Four researchers undertook this task, with peer review at each phase of the process.

This review of research-based peer-reviewed literature was specific to the concept of agricultural literacy development in school-aged students (kindergarten to 18 years old). It acknowledged previous country-specific research while casting a wider net across the world. The method by which this review was conducted has been made transparent, with decisions based upon analytic processes adapted from those recognised in the social science disciplines. Limitations of the findings have been acknowledged.

The search generated 1568 articles for consideration. Elimination of duplicates was performed initially using Endnote X9 and, secondly by manual review of author and title. After duplicates were removed, 442 articles remained. Journal and conference websites were reviewed to remove 287 articles which were not subject to a double-blind peer review process or were incomplete records. Titles and abstracts of the remaining 175 studies were reviewed initially by two members of the research team to determine inclusion of full text review. When two could not reach consensus, a third reviewer was used to reach consensus for inclusion or exclusion of literature at that point of title and abstract screening. There were then 35 full text articles remaining that were divided between three members of the research team and appraised for quality using an adaptation of the Critical Appraisal Skills Programme (CASP) checklist for qualitative research [19] to accommodate not only qualitative methodologies, but also quantitative and mixed methods methodological approaches. This resulted in the exclusion of a further six articles.

The remaining 29 articles were read in full, and details extracted for the analytic matrix which prepared the articles for critique and interpretation: (1) author and year of publication; (2) study problem and aim; (3) research questions and objectives; (4) research design including theoretical framework and methodology; (5) target population including location, number of participants, timeframe; (6) methods of data collection, analysis process/es; (7) ethical approvals and considerations; (8) key findings and summary recommendations; (9) implications for this review's questions and aim. A Microsoft Excel spreadsheet was used to collate these findings. Not all criteria for analysis were provided in every article. Where gaps were identified, they were noted in the matrix. The matrix provided an informed basis for critical analysis and enabled presentation of results relevant to each of the research questions in a transparent, concise, and systematic manner. To overcome differences in terminology used for school grade levels globally, and for appropriate comparison purposes, students are referred to in either age and/or year of schooling (e.g., grades K-8 meaning students from kindergarten to grade 8). The nomenclature for primary and secondary schooling is jurisdictionally dependent therefore these descriptors are used in conjunction with grade designations for consistency throughout.

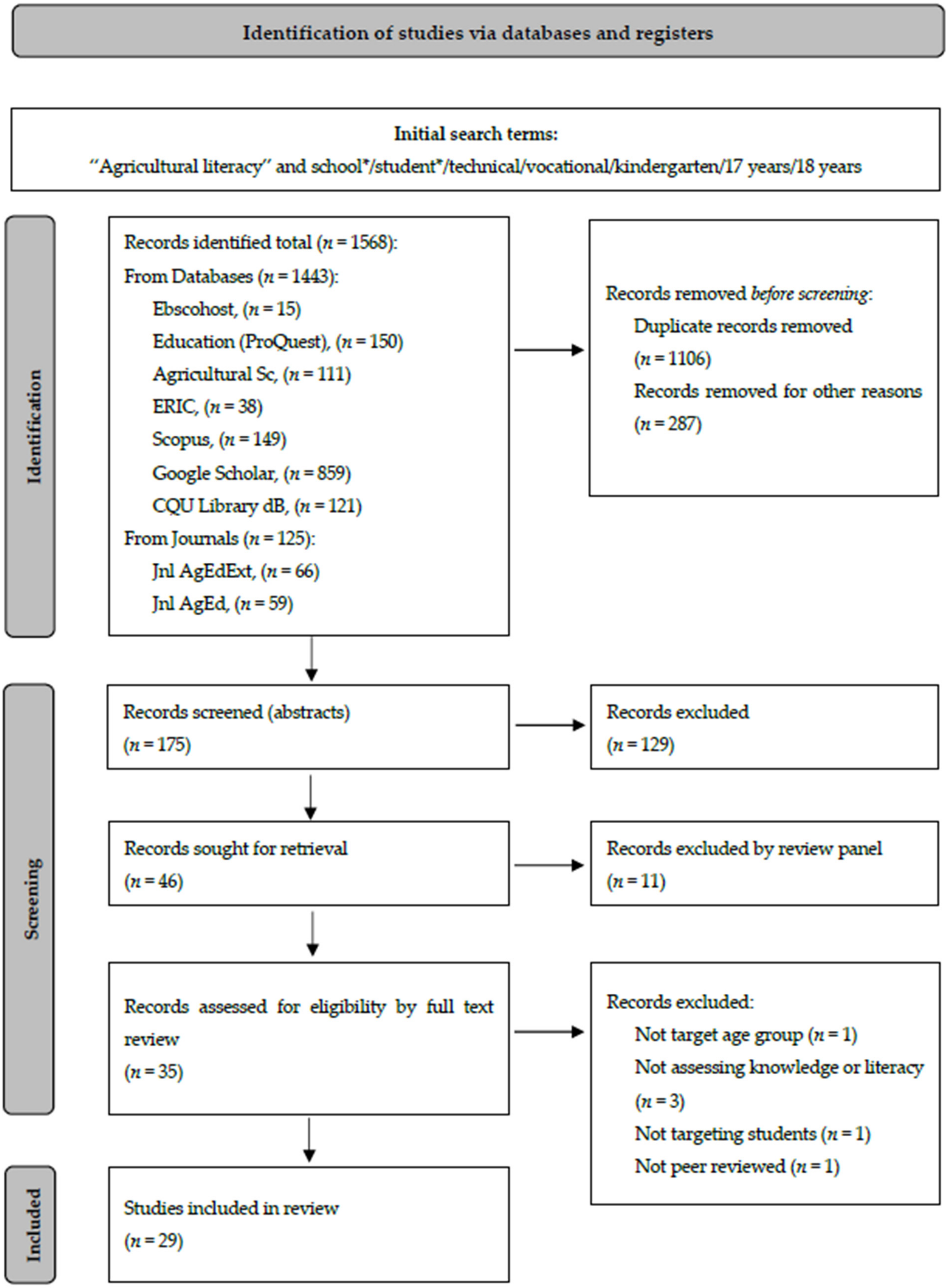

Figure 1. PRISMA Flow Diagram (Adapted from Page et al. 2021). * indicate search terms with multiple endings.

3. Results and Discussion

An overview of the results from a detailed analysis of all 29 full text articles read by the research team can be found in the Appendix A. It includes author reference and location, purpose and/or aim of the research, methods including data collection and analytic processes and ethical considerations, sample size and participants, summary findings and recommendations relevant to this investigation of agricultural literacy.

Of the 29 studies which met the inclusion criteria, 25 were in the USA, with one each in Germany, Korea, India and Nepal [7,20–22] (Figure 2). Most studies were published in journals focused on agricultural education as opposed to general education, with the Journal of Agricultural Education being the predominant source (n = 11/29). Of the 29 articles analysed in depth, 17 targeted students in grades K-8, and 12 targeted older students in grades 9–12. Studies varied in their reach in terms of within schools/classes, across school districts or states or nationally.

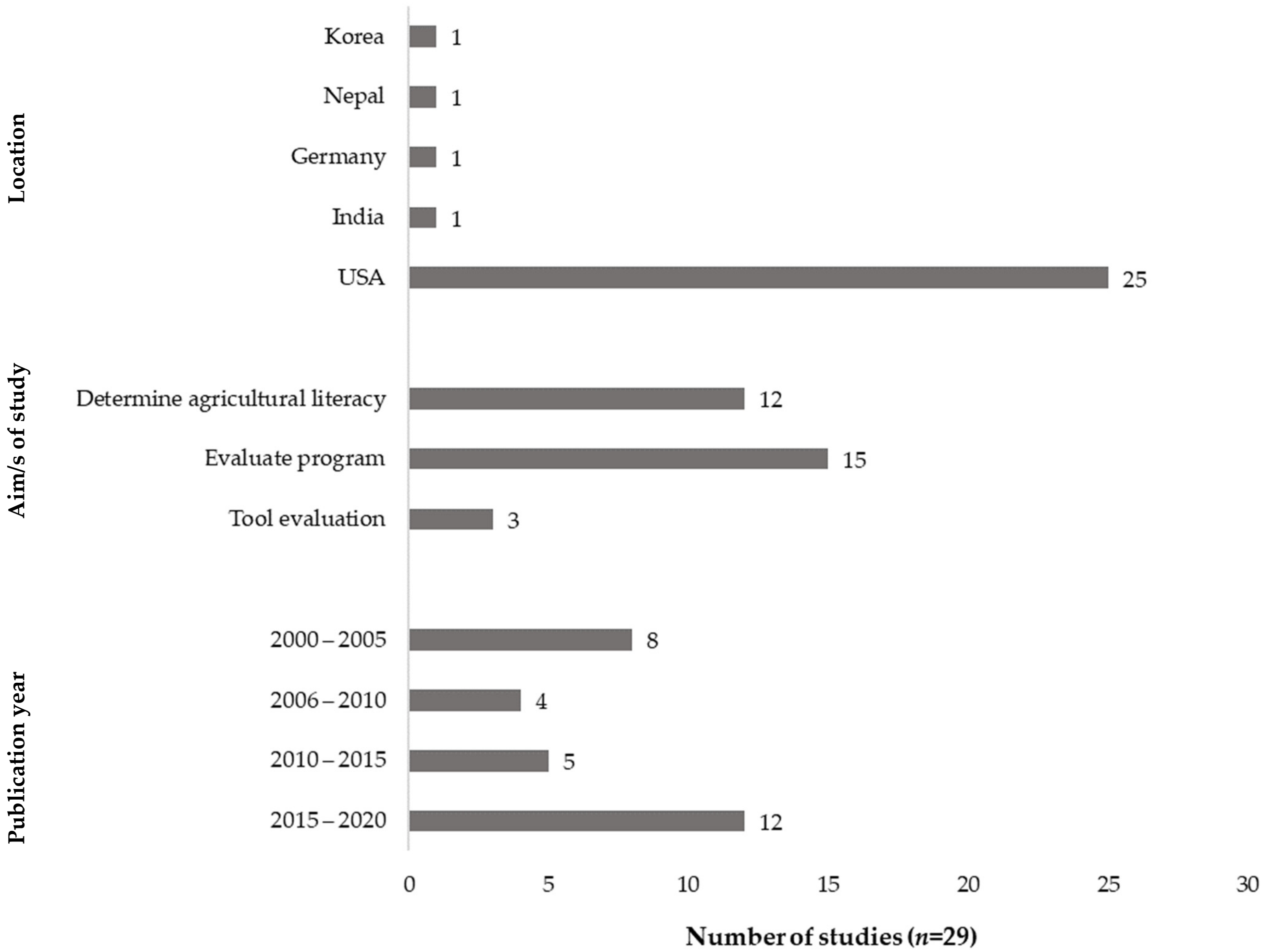

Figure 2. Summary of studies in terms of location, aim/s and publication year.

3.1. Insights Obtained from the Review of Articles as to the Efficacy of the Research to Foster Students' Agricultural Literacy

Researchers sought to identify the purpose of the agricultural literacy research (Figure 2). For those studies which included data from both teachers and students, this review considers only the student component. Consistent with the previous review by Kovar and Ball (2013), the purposes, method and findings of the studies were coded across three themes.

1. Assessing the agricultural literacy of the target population.

2. Evaluating an agricultural education program or curriculum to determine the resultant impact on agricultural literacy.
3. Developing instruments to measure agricultural literacy.

3.1.1. Assessing Agricultural Literacy

Twelve of the 29 studies aimed to assess the agricultural literacy of the target populations [7,13,21–29] (Figure 2). When seeking to determine the agricultural literacy of primary school children, studies focused mainly on grades 3–6 ($n = 6$), with five of these using semi-structured interviews to determine the level of student agricultural knowledge, mostly in relation to origins of food and schema through production and processing stages. The remaining six studies sought to determine the agricultural literacy of students in grades 9–12.

These studies found that students demonstrated low levels of agricultural literacy at both the primary school and high school age levels. At a primary school level Jeong and Choi (2020), through an extensive postal questionnaire to students of 12 schools in Korea, found past student experience with ecological activities such as experiences with learning about plants positively influenced agricultural literacy. This positive experience with vegetation was further supported by the agricultural experience of the teacher. Of the 929 students in urban and sub-urban locations, those with both past positive experiences and a teacher with agricultural experience had higher levels of agricultural literacy than those who did not.

Some studies using semi-structured interviews allowed for more in-depth questioning to explore student responses. Brandt, Forbes, and Keshwani (2017) found student knowledge increased with age and was higher for science, technology, engineering and mathematics (STEM) than agriculture, with students unable to understand the diversity of agriculture and some language concepts used in the NALOs. This was supported by Trexler, Hess, and Hayes (2013) who suggested that agricultural literacy benchmarks may not be age or developmentally appropriate. Overall, students demonstrated low agricultural literacy when looking across the value chain of producing, processing, manufacturing and marketing of food and fibre products. Meischen and Trexler (2003) found that children who raised animals were more knowledgeable in relation to animal production, though they had limited knowledge beyond the production stages of the food chain. For instance, they had little knowledge of non-food products of agriculture and they lacked familiarity with the appropriate language or terminology for such products. This lack of understanding and schema upon which to build knowledge to engage in discourse was later found by Hess and Trexler (2011a and b) and Trexler, Hess, and Hayes (2013) using burger examples which demonstrated students' ability to identify components as agricultural products, but there was still a lack of understanding of the food production journey from paddock to plate or supermarket shelf.

Similarly, students in secondary school (grades 9–12) demonstrated overall low levels of agricultural literacy. Location did make a difference. Rural-based students had higher agricultural knowledge [7,22,28,29]. Gartaula et al. (2020) found rural students with more links to food and fibre production demonstrated higher informal agricultural knowledge, which increased with age; although they had less formal knowledge than their urban counterparts, as demonstrated by academic results as representative of formal knowledge. Pense and Leising (2004) and Pense et al. (2006) compared agricultural education students with general education students and found that whilst the former had higher knowledge, they lacked the depth of understanding representative of agricultural literacy as defined by the NALO benchmarks. Fathima, Krishnankutty, and Krishnan (2016) found rural students to have higher knowledge than urban students, although when comparing curriculum, it was the content which provided the highest impact; students engaged in more project-based experiential learning demonstrated higher agricultural literacy.

3.1.2. Evaluating Agricultural Literacy Programs across the Curriculum

Fifteen studies aimed to evaluate the impact on agricultural literacy of an agricultural education program or curriculum (Figure 2). Of these, nine studies targeted school students in grades K-8. The remaining evaluation impact studies targeted students in grades 9–12 [20,27,29–33]. Bayer, Travis, and Wang (2020) and Luckey et al. (2013) evaluated the 'Kids Growing with Grains' and, 'AgVenture' programs respectively, both short field trips with multi-station demonstrations and hands-on activities to expose students to a range of agricultural activities. All other studies considered the impact of multi-lesson, multi-week activities or curriculum programs. Programs varied in length and complexity, with most incorporating multi-week curriculum inclusive of experiential learning opportunities. Most programs were evaluated using pre- and post-tests to determine if there were any knowledge gains.

For the primary school students, in-class curriculum models were evaluated by Hubert, Frank, and Igo (2000; grades K-8), Leising, Pense, and Igo (2000; grades K-8), Powell, Agnew, and McJunkin (2009, grades 3 and 5) and Vallera and Bodzin (2020, grade 4). Hubert, Frank, and Igo (2000) found improvements in knowledge in all five themes associated with the environment and food and fibre production across most age groups after completion of the university-developed curriculum guide, sample lessons and accompanying website. Leising, Pense, and Igo (2000) found increased knowledge in K-8 students following instruction based on the USA Food and Fibre Systems Literacy framework (FFSL), though outcomes may have been influenced by the whole-of-school approach providing enhanced support to teachers and learners. Powell, Agnew and McJunkin (2009) found grade 3 improvements to be higher than students in grade 5, which may have been influenced by issues with testing procedure in some classes and by the grade 5 test instrument question structure requiring more knowledge to be applied. Higher participation in experiential learning activities generally improved post-test scores of agricultural knowledge.

Vallera and Bodzin (2020) demonstrated increased agricultural knowledge through engagement in the Agricultural Literacy through Innovative Technology (AgLIT) program, a project-based curriculum which contained ten lessons, experiential tasks and a field trip. The AgLIT program required student engagement with an augmented reality iPad game and demonstrated high student engagement with the technology. Boyd and Miller (2005) used a 'Pizz-A-Thon Project' to enhance student knowledge of origins of ingredients, how they were processed and marketed for use in pizzas. Those students in the intervention group attained higher knowledge as a result of the additional enrichment activities undertaken in a two-day off-school program which included exploring agricultural resources on campus and farm. Meunier, Talbert, and Latour (2003) used chicken incubators in grade 4 classrooms across 14 schools, demonstrating engagement with the program increased post-test scores of knowledge. Bayer, Travis, and Wang (2020) demonstrated improved knowledge in grade 3–4 students across 14 schools following attendance at a four-hour field trip, with knowledge demonstrated by a short multiple-choice questionnaire and open response note/drawing.

For secondary school students, hands-on experiential learning generally increased post-test scores. Fritsch, Lechner-Walz, and Dreesmann (2015) and Bradford et al. (2019) both incorporated greenhouse projects to enhance learning. Novel post-testing conducted by Bradford et al. (2019) asked students to nominate if they responded to each question based on knowledge or guessing. Additionally, Bradford et al. (2019) demonstrated an association of teaching method with experiential learning provided students with deeper understanding and concept associations. Paulsen et al. (2017) demonstrated increases in knowledge following completion of a university-developed soil conservation curriculum, though the researchers considered the content may have been too advanced for the students, particularly in relation to the technology lesson. Duncan, Broyles, and Tech (2004), and Duncan and Broyles (2006) found increased agricultural knowledge following a four-week intensive VGSA course [not in school setting-nomination/application based] for gifted students which included intensive course work, field trips and project work. In

Erickson et al. (2020) agriculture and biology students across 16 schools completed seven online poultry industry modules which included knowledge testing before and after modules, demonstrating increased knowledge following module completion.

3.1.3. Developing Instruments to Measure Agricultural Literacy

Three studies aimed to develop an instrument to measure agricultural literacy of students (Figure 2). Pense and Leising (2004) aimed to develop and evaluate a testing instrument based on the FFSL to determine the difference in agricultural literacy between grade 12 students across six schools who were either majoring in agricultural education (previous coursework in agricultural education) or general education (no previous agricultural education coursework). The instrument was determined to be valid and reliable, however this occurred prior to the modernisation of the benchmarks via the NALOs.

More recently, Brune et al. (2020) developed an instrument to measure agricultural knowledge, attitudes and behaviour of children aged 9–13 years in an informal (non-school) setting towards local foods, and to determine the suitability for evaluating the impact of food initiatives targeted to children. They developed the Agricultural Literacy Instrument for Local Foods (ALI-LF), which underwent three phases of testing and refinement, with the results of phases two and three reported in this study. The ALI-LF was found to be reliable and valid for measuring the impact of informal programs conducted outside of the school setting targeted to children aged 9–13 years and offered the ability to be tailored to include relevant local content. The limitations acknowledged of the tool were that as it was developed for informal programs, future use in more formal settings (e.g., classroom, structured programs) may require question review to enable appropriate grading [34].

Longhurst et al. (2020) recognised the need to develop a suitable instrument against which to test agricultural literacy competency as defined by the NALOs. The Longhurst Murray Agricultural Literacy Instrument (LMALI) was developed and evaluated in the study of 227 grade 3–5 students across eight states in the USA and was found to be valid and reliable for testing their proficiencies. Results from the use of the test instrument were considered to be suitable for both formal and informal programs, including formative and summative evaluation before/during/after programs, with results considered appropriate to guide instruction and further program development.

3.2. Recommendations for Innovative Ways of Developing Agriculturally Literate Young People

The recommendations from these agricultural literacy research studies confirm findings and limitations of this review in terms of the significance of, and need for, (a) age appropriate language and design of research instruments; (b) longitudinal studies of agricultural literacy development; (c) an experiential pedagogy inclusive of school-industry partnerships; (d) teachers own agricultural literacy knowledge and capabilities; as well as (e) curriculum frameworks operationalised to reconceptualise twenty-first century agriculture and its portrayal of careers and contributions to society.

Meischen and Trexler (2003) recommended changing agricultural terminology to ensure age appropriateness. This was also more recently recommended by Brandt, Forbes, and Keshwani (2017) to ensure student understanding of terms used in benchmarks, take into consideration age and development level. Brandt, Forbes, and Keshwani (2017) and Hess and Trexler (2011a) concurred that understanding of knowledge gaps (particularly in relation to the processes of agriculture) should be measured, and appropriate knowledge integrated into curriculum to address these gaps. When evaluating programs across grade levels, Bayer, Travis, and Wang (2020) recommended the use of paired questions to determine changes in conceptual understanding. Future tools for evaluation should include measures of cognitive skills to determine the level of problem identification, analysis and action planning [34]. The tool in Longhurst et al. (2020) focused on grades 3–5 and future development of tools for grades K-12 should align with the NALOs, ensuring that all of the benchmarks are included to prevent focus only on measures of selected items.

The importance of extension and farming experience visits/opportunities were highlighted by Meischen and Trexler (2003), Trexler, Hess, and Hayes (2013), Gartaula et al. (2020) and Jeong and Choi (2020), to enable an understanding of schema on which to develop agricultural knowledge. Several authors considered the value of experiential learning and recommended more in future programs. Enhancement of the 'Pizz-A-Thon Project' to include more enrichment activities to enhance knowledge, including field trips/extension activities was suggested [35]. Meischen and Trexler (2003) suggested incorporating the use of agricultural by-products for non-food item production as a method to enhance student knowledge on the wider impact and importance of the industry. An increase in hands-on learning was recommended in both primary school aged [36] and high school aged students [37], with exposure allowing them to have a stronger connection with agriculture from these experiences, particularly if lacking exposure to agriculture in their informal settings [7,24].

Whitehead and Estepp (2016) suggested that programs should be reviewed to understand the depth and breadth of agricultural knowledge attainment and knowledge retention. Jeong and Choi (2020) recommended the incorporation of agriculture concepts into lessons prior to grade five, and not limited to senior primary school students. Pense et al. (2006) suggested more research to determine agricultural literacy on entering the high school grades, which would demonstrate retention of knowledge from earlier learning. This may assist in determining if the curriculum is too difficult for students' level of understanding, a potential issue postulated by Paulsen et al. (2017). Bayer, Travis, and Wang (2020) included family engagement activities to encourage continued learning in the home environment and suggested future research to determine the influence of school learning on knowledge sharing with family/friends.

Whilst online modules were found to increase agricultural knowledge, Erickson et al. (2020) recommended the incorporation of prompts for brief discussion or hands-on activities following each module. Ensuring teachers have full access to the online resources and support prior to implementation, will allow teachers to provide further guidance to students during the module completion, and prepare for discussion and activities post-completion [32].

Several authors highlighted the importance of supporting teachers to integrate agriculture into their teaching through professional development. Boyd and Miller (2005) recommended teacher training in the 'Pizz-A-Thon Project' to increase their own agricultural knowledge and identify opportunities for engagement activities in their local communities. Future research is required to determine the influence of teacher behaviour and experience on student knowledge acquisition, and the ability to make connections to the content [38]. This would enhance a cross disciplinary approach and allow building of connections and knowledge associations [20]. Trexler, Hess, and Hayes (2013) recommended professional development to enhance teachers' ability to draw on past student experiences and knowledge, and development of appropriate class activities to expand on this. To increase teacher confidence, particularly with integrated curriculums, development, and provision of support materials for programs are recommended to reduce time constraints on teachers and to overcome learner misconceptions [39].

Jeong and Choi (2020), Meischen and Trexler (2003), Smith, Park, and Sutton (2009) and Whitehead and Estepp (2016) concurred that curriculum should portray modern agriculture, to re-conceptualise the notion of farming. Meunier, Talbert, and Latour (2003) recommended that program concepts be reviewed to ensure they are not turning students away from pursuing agricultural careers. This may lead to re-valorisation of the industry generally, as recommended by Gartaula et al. (2020), to better promote future engagement in agricultural careers. Duncan and Broyles (2006) suggested the VGSA program model is appropriate for development of agricultural literacy, however recommended longitudinal studies following program attendance to determine future student-industry engagement.

3.3. Limitations

Three major limitations of these findings are represented by the largely first world developed nations research scope coupled with a lack of jurisdictional policy oversight for the enactment of agricultural literacy at systemic levels of curriculum design and delivery. Furthermore, since the USA focused review conducted by Kovar and Ball in 2013, there has been little penetration of agricultural literacy research into mainstream education research. These limitations highlight the elusiveness of this agricultural literacy concept once decoupled from the notion of agricultural education as a separate subject or course in a school curriculum. Within the boundaries of this review topic, it was not possible to determine the extent to which agricultural literacy is acknowledged, valued, embedded in curriculum, and measured within and across schools or systemic jurisdictions nationally and internationally.

4. Conclusions

As the global population increases, an agriculturally literate population is fundamental for sustainable and efficient food, fibre and technological supply chains to ensure high levels of human health and safety. This focused, systematically ordered review of agricultural literacy research using the PRISMA protocol, elicited five key findings. First, definitions of agricultural literacy have evolved in recent decades from a mere knowledge or awareness of limited aspects of agriculture, to be a measure of a deeper understanding of the economic, social, science and technology aspects of the industry coupled with the ability to synthesize and communicate such knowledge. Second, agricultural literacy is developed throughout the years of schooling by both formal and informal education and experiences. Third, informal agricultural knowledge may be gained through numerous sources, including working in or having links to family or close friends' agricultural businesses; general discussions in non-farming families and social groups; and traditional and social media sources. Fourth, misconceptions or a lack of knowledge of the wide-ranging agriculture industry and its full production processes are found even among those with informal familial knowledge networks. Finally, developing agricultural literacy in school-aged children through formal education is critical to bridge the knowledge gap, develop an understanding of the breadth and influence of agriculture's production processes, overcome negative perceptions and stereotypes, and encourage (eventual) workforce participation. These findings should be considered when designing and undertaking future research aimed to increase the agricultural literacy of school-aged children to ensure programs are effective in meeting their objectives. Programs should venture into other areas of the curriculum because if they remain limited in their integration to agricultural classes, their impact on the wider population will be diminished. Agricultural concepts can be easily integrated into other disciplines such as science, technology, engineering, and mathematics (STEM) as demonstrated by many of the studies reviewed. This presents the opportunity to develop agricultural literacy through both formal and informal educational experiences for school-aged students, without the need for a prescribed agriculture curriculum.

With the majority of agricultural literacy research being undertaken in the USA, policymakers in other countries should consider the development and implementation of a framework similar to the National Agricultural Learning Outcomes (NALOs). The NALOs provide the most comprehensive learning framework across the globe against which to measure student agricultural literacy. By outlining the knowledge standards from grades K-12 which, 'identify what an agriculturally literate person should know and be able to communicate about agriculture at each grade level band' [40] they provide benchmarks to increase uniformity across the national education system in the USA. Whilst the NALOs are not mandatory, they are supported by the National Agricultural Literacy Curriculum Matrix (NALCM) which provides access to appropriately benchmarked, peer reviewed lesson plans and experiential learning activities for teachers [40]. A similar framework and associated support in other countries would encourage those involved in education to develop, implement and evaluate programs aimed to increase the agricultural literacy of school-aged children.

Policymakers and industry organisations could also use these findings to design and engage school-aged children in formal and informal programs to increase their knowledge and appreciation of the agricultural sector. By increasing their agricultural literacy, students' aspirations for a career in agriculture will be supported which in turn will help to address workforce shortages in the industry.

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Appendix A

Table A1. Analytic matrix of results.

Author, Year, Location	Aim [1]	Method/s	Sample Size & Participants	Findings	Recommendations
Bayer, Travis & Wang, 2020, USA	EP	Survey (5Q Y/N) & notes following 4-h field trip	Grade 3–4, 14 schools, *n* = 3076 (included 185 teachers)	94% understood 4/6 concepts presented, 87% understood the remaining 2/6 concepts	Use existing paired questions across grades to see changes in conceptual understanding. Look at if/how students share knowledge gained with family and influence on family behaviours.
Boyd & Miller, 2005, USA	EP	Pre-test/Post-test. 3 groups (control, low, high participation). Highest participation in low group (*n* = 42)	Middle school (Grade 6–8), 3 schools, *n* = 61,	The higher participation group improved post-test. Control and lower participation group saw no difference. Issue—Control group was older, more rural, more with parents in agriculture and may have had higher baseline knowledge.	Inclusion of more enrichment activities in the base program (like the higher participation group) to enhance knowledge. Teachers to incorporate field trips/extension activities. Teacher PD on agriculture more broadly plus the 'Pizz-A-Thon' kit and help with linkages to community activities. Future studies on 'Pizz-A-Thon' should be larger scale and inclusive of broader range of communities.
Bradford et al., 2019, USA	EP	Pre-test/Post-test. 3 groups (1 = Control, 2 = direct instruction, 3 = experiential learning). 6 lesson intervention	10th grade biology students, 3 schools, *n* = 57	Interventions: Post-test scores significantly higher, group 3 (experiential learning) highest. Pre-test: mean each group-unacceptably low knowledge.	More experiential learning opportunities.

Table A1. *Cont.*

Author, Year, Location	Aim [1]	Method/s	Sample Size & Participants	Findings	Recommendations
Brandt, Forbes & Keshwani, 2017, USA	DAL	Semi-structured interviews and test instrument	Grade 3–5, 2 schools, $n = 35$	Student knowledge higher for STEM than agriculture (as defined by NALO), with the difference greater for the higher grades. Overall agricultural literacy increased with grade. Students do not understand the diversity of agriculture. Some NALOs contained language students were unable to understand.	Focus on student understanding of the terms used in the NALOs, revised as appropriate. Curriculum to be developed to address gaps in NALO knowledge and integrate STEM with agriculture.
Brune et al., 2020, USA	TE	3 phase testing of instrument	Age 9–13 yrs, attended agri-tourism activity, $n = 205$	Tool developed is reliable and valid to use in informal settings. Relevant for measuring impact of food initiatives geared towards children. Tool offers ability to tailor for local settings.	Future tools to include cognitive skills—working memory & fluid reasoning—issue identification, analysis, action planning. Tool developed for informal settings; formal settings (classroom, structured programs) may need revision of questions to allow grading.
Duncan & Broyles, 2004, USA	EP	Pre-test/Post-test. 4-week course work	Grades 9–12, VGSA, $n = 86$, gifted students	Increased agricultural knowledge post-test.	Future opportunities at the VGSA program should be open to all students and not just "gifted" students.
Duncan & Broyles, 2006, USA	EP	Pre-test/Post-test. 4-week course work	Grades 7–12, VGSA 2 cohorts, $n = 136$, 20% from rural background, gifted students	Post-test scores higher.	Use this as model for other institutions—included field work, wide range of exposure to agriculture/biotech/agribusiness and experiential learning. Future review to determine if those students engaged in program pursued agriculture related careers.

Table A1. *Cont.*

Author, Year, Location	Aim [1]	Method/s	Sample Size & Participants	Findings	Recommendations
Erickson et al., 2020, USA	EP	Pre-test/Post-test. Poultry module completion—7x online modules	High school (junior & senior), agriculture and biology students, 16 schools, 23 classrooms, n = 499 (169 complete responses)	Post-test scores higher.	Online program could be enhanced by prompts for short 5–10 min discussions/hands on activity following module completion. Provide teachers with support/discussion prior to and during program rather than after. Facilitator guide provided before implementation, but teachers should have full access to review modules prior to class implementation.
Fathima, Krishnankutty & Krishnan, 2016, India	DAL	Structured interview, 50Q (open, Y/N, M/C)	High secondary grades, 8 schools, n = 393, urban & rural locations	Rural students' knowledge higher than urban, though curriculum had higher impact. Those with more project-based hands-on learning had more knowledge.	Future integration of more experiential learning to align students with agriculture.
Fritsch, Lechner-Walz & Dreesmann, 2015, Germany	EP	Pre-test/Post-test. 2 groups: 1 = Control (n = 48), 2 = activity (n = 74)	Grade 5–13, 2 schools, 7 classes (4 intervention), n = 122	Post-test scores higher for activity group. Girls above boys in pre- and post-tests.	Ensure focus is not on one plant only—provide extra learning material to incorporate other plants/seeds etc to allow transfer of knowledge and associations. Combine instruction regarding crops with other school subjects to build connections with daily life.

Table A1. *Cont.*

Author, Year, Location	Aim [1]	Method/s	Sample Size & Participants	Findings	Recommendations
Gartaula et al., 2020, Nepal	DAL	Knowledge tests and evaluation of academic results as indication of capacity to learn	Grade 9–12, 6 schools, *n* = 226, urban & rural locations	Rural students scored higher on informal knowledge and lower in formal results. Rural students have more links to agriculture, often assisting on family farms. Urban students had few links to agriculture. Informal knowledge increased with age—more experienced.	Schools should integrate extension services in schools to enhance knowledge. Schools to move towards revalorisation of traditional-food literacy.
Hess & Trexler, 2011a, USA	DAL	Semi-structured interviews	Grade 4–6, *n* = 18, recruited through youth club	78% correct identification of components of cheeseburger, but low result (28%) for food origin and farm to plate—lacked scheme for discourse. Agricultural experiences did not influence their understanding food journey from origin to plate.	Future research to understand gaps in knowledge of processes (processing, manufacturing and marketing) and incorporate appropriate knowledge into curriculum.
Hess & Trexler, 2011b, USA	DAL	Semi-structured interviews	Grade 4–6, *n* = 18, recruited through youth club	Lack of understanding and lack of scheme upon which to build knowledge.	Although students had the same formal education, differences in their understanding and lack of scheme to build upon, highlights the importance of informal experiences.
Hubert, Frank & Igo, 2000, USA	EP	Pre-test/Post-test	Grade K-8 (4 grade brackets), 3 schools, 3 states, *n* = 800, urban & rural schools	Post-test scores higher for all 5 themes and age grouping except 2, suggesting guide may influence student learning. Younger students higher gain in agriculture knowledge.	Recommendations focus on the 'guide' and the associated website, but lack direction to address agricultural literacy.

Table A1. *Cont.*

Author, Year, Location	Aim [1]	Method/s	Sample Size & Participants	Findings	Recommendations
Jeong & Choi, 2020, Korea	DAL	Postal questionnaire	Grade 5–6, 12 schools, n = 929, urban & sub-urban locations	Student experience with vegetation likely to have higher agricultural literacy. Teacher's agricultural experiences improved student agricultural literacy.	Interdisciplinary lesson design and teaching of agricultural concepts to improve literacy. Engagement in extension type programs for farming experiences and agricultural career awareness. National curriculum should be redesigned to reflect changes to industry to create positive perception of industry and future careers. Bring agricultural concepts into lessons younger than grades 5–6. Tools to measure agricultural literacy to be improved and incorporate changing industry.
Leising, Pense & Igo, 2000, USA	EP	Pre-test/Post-test. 2 groups (Control-one state, intervention), 16–21Q—pictures/text/both	Grade K-8 (4 grade brackets), 3 states, n = 21	Students had some knowledge of FFSL pre-test. Intervention—student knowledge increased most in 3/5 themes. Whole of school approach may have led to overall student achievement.	Future research to determine influence of teacher behaviour on student knowledge acquisition. Field testing the standards and benchmarks to determine how to implement across disciplines.
Longhurst, Judd-Murray, Coster & Spielmaker, 2020, USA	TE	45Q based on NALOs, consolidated to 15Q	Grade 3–5, 8 states, n = 227	Tool valid and reliable for testing agricultural proficiency for grades 3–5 against NALOs. Could be used formative/summative tool to guide instruction and programming (formal and non-formal programs). Suitable for use as tool before, during and after instructional programs.	Increase number of items in tool to improve utility. Expand to include other age brackets. Ensure that future tools cover all of the benchmarks to prevent measures only against selected items.

Table A1. *Cont.*

Author, Year, Location	Aim [1]	Method/s	Sample Size & Participants	Findings	Recommendations
Luckey, Murphrey, Cummin & Edwards, 2013, USA	EP	Pre-test/Post-test	Grade 4, 2 schools, $n = 41$	Potential increase in knowledge post participation, but conclusions of the study cannot be solely attributed to activities of the 'AgVenture' program.	Field trips have a place to increase agricultural literacy, but survey design needs to be carefully considered for accurate evaluation of a program.
Meischen & Trexler, 2003, USA	DAL	Semi-structured interviews	Grade 5, 1 school, $n = 7$, rural location	Children who raised animals—more elaborate description of production. Limited knowledge on non-food products from animals and size/scope of modern agriculture. No better for processing of meat products. Lack of use of terminology aligned to benchmarks.	Future studies may recommend changing benchmark terminology to be age appropriate. If students understand use of by-products for non-food items, they may better understand importance of agriculture on their lives. Re-conceptualise student notion of farms—change curriculum to a more accurate portrayal of modern agriculture.
Meunier, Talbert & Latour, 2003, USA	EP	Pre-test/Post-test, 2 groups (control, intervention)	Grade 4, 14 schools, $n = 736$	Post-test scores higher for categories except 1. Materials increase knowledge re professions. Conflicting results in intervention group pre-test.	Some concepts may need to be reviewed to determine if they are turning students away from agricultural careers. Hands on learning in more programs.
Paulsen, Polush, Clark & Cruse, 2017, USA	EP	Pre-test/Post-test, 2–4 week program	Grade 9–12, $n = 52$	Significant increase post-test scores.	Consider if the curriculum is too difficult for their level of understanding or if it was related to teacher adaptation of the materials.

Table A1. *Cont.*

Author, Year, Location	Aim [1]	Method/s	Sample Size & Participants	Findings	Recommendations
Pense & Leising, 2004, USA	DAL & TE	Instrument developed based on FFSL. MC questions. Compared Ag Ed students vs. General Ed students	Grade 12, 6 schools with Ag Ed programs, $n = 330$, rural and urban locations	Rural schools lower score than urban schools, increase in one theme only between Ag Ed group and General Ed group. Overall lack of agricultural literacy as defined by FFSL framework (<50%). Instrument developed was valid and reliable.	Future research to determine why rural students less knowledgeable than urban. Need future development of curriculum in all disciplines to integrate ag concepts at all school levels, building on instructional activities.
Pense, Beebe, Leising, Wakefield & Steffen, 2006, USA	DAL	Multiple choice questions. Group comparison—Ag Ed students vs. General ed students	Grade 12, 5 schools with Ag Ed programs, $n = 202$, rural location	Both groups had some agricultural knowledge. Ag Ed students higher scores, rural students (regardless of Ag Ed) higher in all 5 themes of FFSL. Overall lack of agricultural literacy as measured by the FFSL.	Development of resources and curriculum to integrate agriculture concepts into all school disciplines. Use of external extension, industry leaders etc for teacher PD of cross discipline teachers (particularly science) to increase agricultural literacy of teachers. More research required to determine agricultural literacy of students entering high school.
Pense, Leising, Portillo & Igo, 2005, USA	EP	Pre-test/Post-test, MC and text questions. 2 groups (control, intervention), trained vs. untrained teachers in AITC program	Grade K-6 (4 grade brackets), 4 states, $n = 1734$	Intervention group—gains in all age brackets. Teacher training made positive difference in student knowledge, most significantly in lower grades.	Focus needs to shift between FFSL framework themes. Teacher training and PD should be considered for all programs.
Powell, Agnew & McJunkin, 2009, USA	EP	Pre-test/Post-test, same test pre & post (start and end of semester), lessons aligned to FFSL	Grade 3 & 5, 3 schools, $n = 233$	3rd grade higher on pre & post-tests than 5th (may be due to higher application requirement in 5th grade test). Some classes testing poorly conducted.	To build knowledge, need to develop and implement integrated curriculum rather than infusion lessons, which are limited by time, resources and teacher experience.

Table A1. *Cont.*

Author, Year, Location	Aim [1]	Method/s	Sample Size & Participants	Findings	Recommendations
Smith, Park & Sutton, 2009, USA	DAL	Anon survey, 21Q—statements with Likert scale	Grade 9–12, 3 schools, *n* = 318	Students not agricultural literate, on-farm students slightly more knowledgeable.	Agriculture teachers to promote more modern representation of farming and look at student perception development.
Trexler, Hess & Hayes, 2013, USA	DAL	Semi-structured interviews	Grade 4–6, *n* = 18	Existing ag literacy benchmarks may not be age or developmentally appropriate. No understanding of crop origins and selection of plants/animals based on traits.	Incorporate student experience to develop schema—school gardens, farm trips, making products in class. Review technology benchmarks for agricultural literacy. Teacher PD to help draw on student past experience/knowledge and development of class activities to expand.
Vallera & Bodzin, 2020, USA	EP	Pre-test/Post-test, 27 MC questions, 2 groups (control, intervention—10 lessons, tasks, field trip)	Grade 4, multiple schools, *n* = 80	Intervention group increased agriculture knowledge. Students engaged with the technology and allowed overlap with other subject knowledge.	Teacher PD and support materials to increase teacher confidence and reduce time requirements.
Whitehead & Estepp, 2016, USA	DAL	Used Frick's Agricultural Awareness Survey (Frick et al., 1995)	High school (14–17 yrs), 41% aged 16–17 yrs, 35 schools, *n* = 135	Overall fail in agricultural literacy score. Ethnicity differences (non-Hispanic higher), rural vs. urban differences. Lack of knowledge about agricultural career options (Hispanic higher).	Review of programs to understand the depth and breadth of agricultural knowledge and level of knowledge retention. Teachers should emphasize agricultural career options available. Review minority engagement with agriculture programs.

[1] Aims: DAL (Determine agricultural literacy); EP (Evaluate program); TE (Tool evaluated).

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